The replacement of hydrogen by a compound radical, aniline—amylaniline; and water, alcohol, ether (according to Williamson's theory). Of hydrogen by oxygen—alcohol, acetic acid; ether, acetic ether; and carvene, carvole, eugenic acid. Of hydrogen by peroxide of nitrogen—benzole, nitrobenzole, dinitrobenzole (in solution); glycerine, nitroglycerine; and amylic alcohol, nitrate of amyl. Of hydrogen by chlorine—benzole, chlorobenzole, terchlorobenzole; and the substitution of chlorine by bromine—terchloride of phosphorus, terbromide of phosphorus; chloroform, bromoform; and bichloride of chlor-ethylene, bibromide of chlor-ethylene, bibromide of brom-ethylene. When hydrogen is replaced by some other body, there is generally an increase of the actual refraction and dispersion; but this is due to the increased weight, hydrogen having a very low actual, but a very high specific influence on the rays of light. In each of the five instances of two substitution-products, as, for instance, chlorobenzole and trichlorobenzole, the lower one always retains in its optical properties an intermediate position between the original substance and the higher product.

These experiments on substitution sufficed to show, as the examination of isomeric bodies had done, that the special influence exerted on the rays of light by the elements of a compound is greatly dependent on the manner of their combination.

The following is given as a generalization approximately, if not absolutely true:—Every liquid has a specific refractive energy composed of the specific refractive energies of its component elements, modified by the manner of combination, and which is unaffected by change of temperature, and this refractive energy accompanies it when mixed with other liquids.

III. "On the Change of Form assumed by Wrought Iron and other Metals when Heated and then Cooled by partial immersion in Water." By Lieut.-Col. H. Clerk, R.A., F.R.S. Received February 9, 1863.

Origin of the Experiments.—A short time ago, when about to shoe a wheel with a hoop-tire, to which it was necessary to give a bevel of about $\frac{3}{8}$ths of an inch, one of the workmen employed suggested that the bevel could be given by heating the tire red-hot and

then immersing it one-half its depth in cold water. This was tried, and found to answer perfectly, that portion of the tire which was out of the water being reduced in diameter. The tire was 3 inches wide, $\frac{1}{2}$ inch thick, and 4′ 2″ in diameter.

As this result was curious and not generally known, I considered it desirable to institute some further experiments in order to try how far, by successive heatings and coolings, this change of form could be augmented, and also whether the same effect could be produced on other metals than wrought iron.

Mode of carrying out the Experiments.—The experiments were made on cylinders of wrought iron of different dimensions, both hollow and solid; immersed, some to one-half of their depth, others to two-thirds; also on similar cylinders of cast iron, steel, zinc, tin, and gun-metal.

The specimens experimented on were all accurately turned in a lathe to the required dimensions, which were carefully noted; they were then heated to a red heat in a wood-furnace used for heating the tires of wheels. As soon as they had acquired the proper heat, they were taken out and immersed in water to one-half or two-thirds of their depth (as stated in the experiment). The temperature of the water ranged from 60° to 70° Fahr.

The specimens were allowed to remain in the water about two minutes, in which time the portion in the air had lost all redness, and that in the water had become sufficiently cool to handle. These alternate heatings and coolings were repeated till the metal showed signs of cracking or giving way.

The dimensions were noted after every five heatings. The circumferences were measured in preference to the diameters, as the true circular form was liable to alter.

General Results.—It will be seen by an inspection of the figures that the general effect is a maximum contraction of the metal about one inch above the water-line; and that this is the same whether the metal be immersed one-half or two-thirds of its depth, or whether it be nine, six, or three inches deep. With wrought iron the heatings and coolings could be repeated from fifteen to twenty times before the metal showed any signs of separation; but with cast iron after the fifth heating the metal was cracked, and the hollow cylinder separated all round just below the water-line after the second heating.

Cast steel stood twenty heatings, but was very much cracked all over its surface. As respects the change of form of cast iron and steel, the result was similar to that in wrought iron, but not nearly so large in amount. The cast iron did not return to its original dimensions, but the smallest diameter was about one inch above the water-line.

Tin showed no change of form, there being apparently no intermediate state between the melting-point and absolute solidity. Brass, gun-metal, and zinc showed the effect slightly; but instead of a contraction just above the water-line, there was an expansion or bulging.

The effect on wrought iron is best seen in the solid cylinder (figs. 9 and 10), where the displacement of particles just above the water-line appears to be compensated by the bulgings at the two extremities.

The specimens of wrought iron were submitted by Mr. Abel (Chemist to the War Department) to chemical analysis, and he informs me that he found nothing noteworthy in the composition of the metal; nor was there any appreciable difference in the specific gravity of the metal taken from different parts of the specimen. It appears therefore to be simply a movement of the particles whilst the metal is in a soft or semifluid state.

The following is an account of the experiments, which were carried out under the superintendence of Mr. Butter, Draughtsman of the Royal Carriage Department, to whom also I am indebted for the accompanying diagrams. The exact dimensions of each specimen before and after heating are given in a tabulated form at the end of the paper, to facilitate comparison.

In figs. 22 and 23 the changes in form of the 9″ cylinders (one immersed one-half, the other two-thirds its depth) are shown in section after every five heatings (half the full size).

Experiment. 1—A 4 ft. 2 in. hoop-tire of 3 inches breadth and $\frac{3}{8}$ths inch in thickness (fig. 1) was heated and cooled by being immersed to half its depth in cold water five times, by which the effect shown in fig. 2 was produced.

Fig. 1.

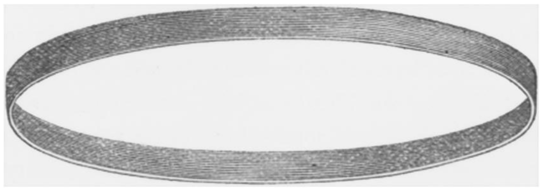
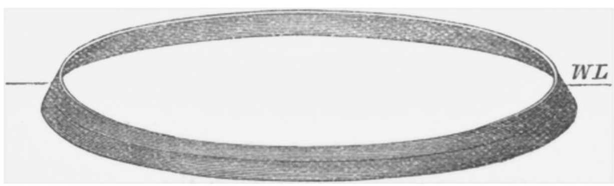


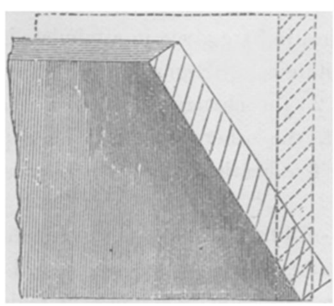
Fig. 2.



One-eighteenth of full size.

The upper edge, or that cooled in air, had contracted 8 inches, or $\frac{1}{20}$th its entire length, and slightly increased in thickness; while the lower edge, cooled in water, had expanded ·875 inch, making a difference between the two circumferences of 8·875 inches. The breadth remained unaltered (3 inches), and kept perfectly straight.

Fig. 3.



Section showing the amount of contraction. One-half the full size. The dotted lines show the original form.

The quality of the iron was afterwards tested by pieces taken from the upper and lower edges, and also from the centre; the fibrous

condition had remained unchanged, the specific gravity had not altered appreciably, and there appeared to be no deterioration in any part of it.

Experiment 2.—Two hollow cylinders of wrought iron, 12 inches diameter and $\frac{1}{2}$ inch thick each, and respectively 9 inches and 6 inches deep, were heated to redness, and cooled by half-immersion in cold water twenty times; for effects see figs. 4 and 5.

Fig. 4.

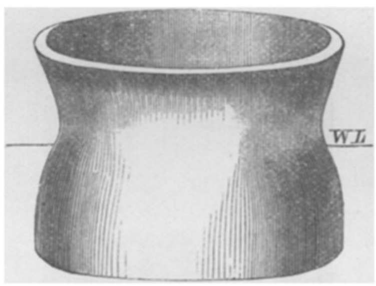
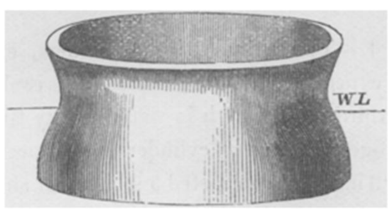


Fig. 5.



One-eighth of full size.

The 9-inch cylinder did not alter on the upper edge, cooled in air; but the lower edge, cooled in water, contracted ·6 inch, and the circumference, at about one inch above the water-line, was reduced 5·5 inches; the internal surface had increased in depth ·35 inch.

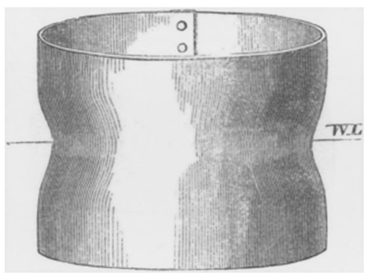
The small cylinder diminished ·7 inch on the upper edge, increased ·3 inch on the lower edge, and contracted 5·25 inches at about 1 inch above the water-line; the internal surface had increased in depth ·3 inch.

Experiment 3.—A cylinder of very thin wrought iron, so thin that

it could not be welded, and was therefore riveted, of the same external dimensions as the 9-inch one of the foregoing experiment, was heated to redness and cooled by half-immersion ten times, in order to test the effect when the thickness of the metal was reduced as much as possible.

The upper and lower edges were not altered materially, while the greatest contraction took place on the water-line, instead of 1 inch above it as in the last experiment, and amounted to 3·5 inches. The depth measured on the curve had increased ·15 inch (see fig. 6).

Fig. 6.



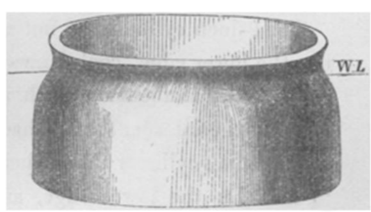
One-eighth of full size.

Experiment 4.—Two wrought-iron cylinders, exactly similar to those used in experiment 2, were heated and cooled by being immersed to two-thirds their depth in water twenty times.

The upper edge of the large cylinder was reduced 2·1 inches, and the lower edge ·9 inch; it contracted 5·9 inches at about an inch above

Fig. 7.

Fig. 8.



One-eighth of full size.

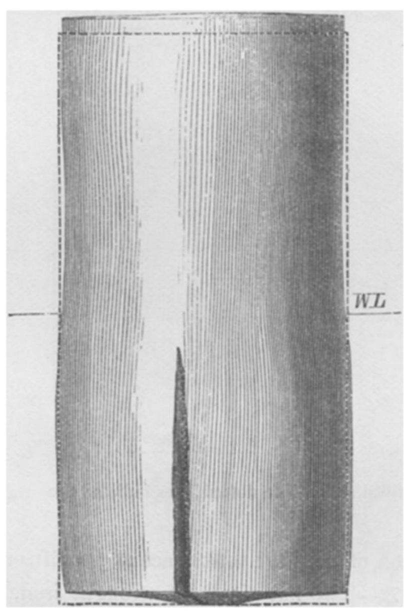
the water-line, and the inside surface had increased in depth ·35 inch (see fig. 7).

The upper edge of the small cylinder was reduced in circumference 3·6 inches and the lower edge ·65 inch, while the greatest contraction at about one inch above the water-line was 4·6 inches; and the internal surface had increased ·15 inch in height (see fig. 8).

Experiment 5.—A solid cylinder of wrought iron, 3 inches in diameter and 6 inches deep, was heated and cooled by being immersed half its depth in water fifteen times.

The greatest contraction took place a little above the water-line and on the lower edge, being in each case ·45 inch; the upper edge was reduced only ·1 inch.

Fig. 9.



One-half of full size. The dotted lines indicate the original form.

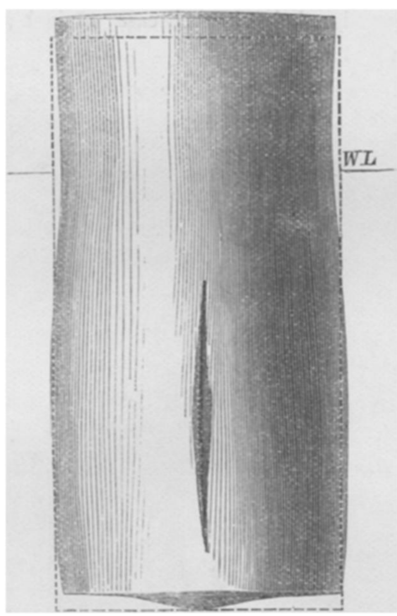
A swell of metal took place on the two ends, but was greatest on the bottom, or that cooled in water, being ·15 inch in height.

The fibre of the iron opened at the fifteenth cooling (see fig. 9).

Experiment 6.—A wrought-iron cylinder exactly similar to the last was cooled by being immersed to two-thirds its depth fifteen times.

The greatest contraction, amounting to ·4 inch, took place a little above the water-line; the upper edge was ·05 inch smaller, and the lower edge ·35 inch, while the swellings on the ends were nearly the same as in the last experiment (see fig. 10).

Fig. 10.



One-half of full size. The dotted lines indicate the original form.

The separation of the fibre took place at the fifteenth cooling.

Experiment 7.—Two flat pieces of wrought iron, each 12 inches long, 6 inches deep, and ·5 inch thick, were heated and cooled twenty times, one being immersed to half, and the other to two-thirds its depth in water.

That immersed one-half had contracted or become indented on the ends fully ·3 inch; the other had similar indentations, but to only

one-half the amount. They were both turned up into the form of an arc, had thickened on their upper edges, and increased ·1 inch in thickness where the contractions on the ends took place (see figs. 11 and 12).

Fig. 11.

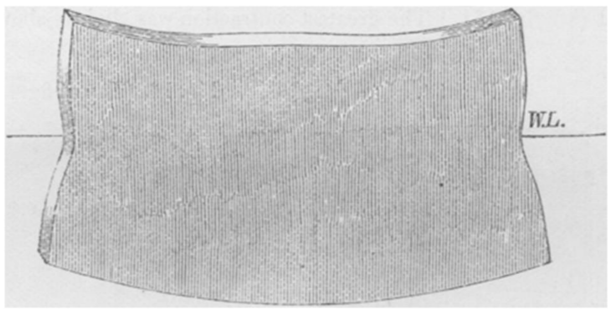
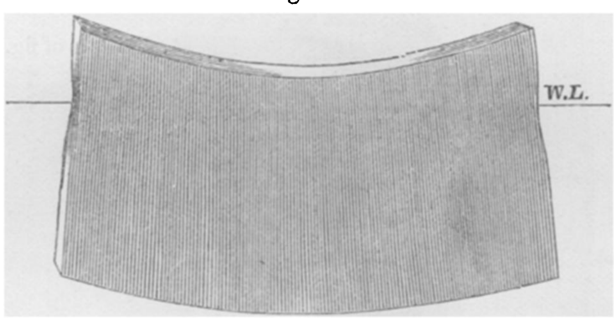


Fig. 12.



One-fourth of full size.

Experiment 8.—Two hollow wrought-iron cylinders, 9 inches deep and 12 inches in diameter, were heated and cooled, one by simple exposure to air (fifteen times), and the other by total immersion in water (ten times). No alteration occurred in the form of either*.

* The cylinder which was cooled in air weighed, before the experiment, 49 lbs. 14·5 ozs., and after the experiment 49 lbs. 11 ozs., showing a loss by scaling of 3·5 ozs.

During the progress of the experiment, however, it was frequently weighed, and was found each time to have increased in weight up to the tenth heating, at which

Experiment 9.—A solid cast-steel cylinder, of the same dimensions as that used in Experiment 5, was heated and cooled by half-immersion twenty times.

The effect obtained was similar to that produced upon the solid wrought-iron cylinders, but the breaking up of the structure was different (see fig. 13). The greatest contraction was slightly above the

Fig. 13.

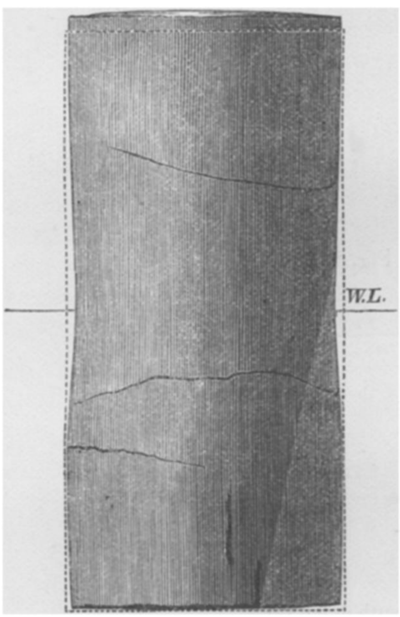


Fig. 14. (Top of fig. 13.)

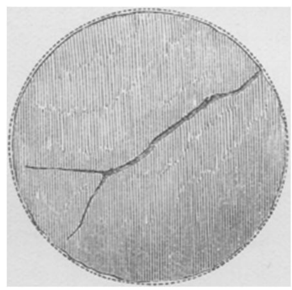
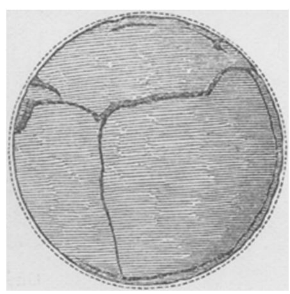


Fig. 15. (Bottom of fig. 13.)



One-half of full size. The dotted lines indicate the original figure.

water-line, and amounted to ·38 inch; the bulgings on the ends were ·075 inch, being much less than on the wrought-iron cylinders.

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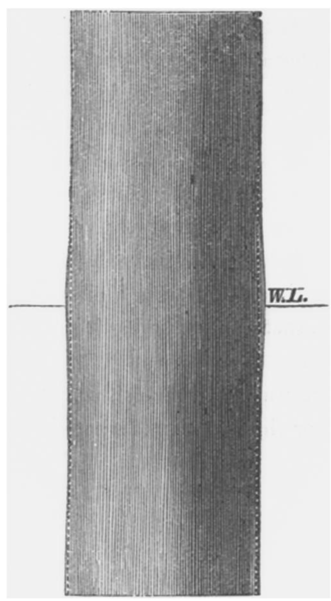
point it weighed 50 lbs. 1·125 oz., or 2·625 ozs. heavier than it was at the commencement; from the tenth to the fifteenth heating the accumulated scales peeled off, and the weight was gradually reduced to that stated above.

That which was cooled in water weighed 50 lbs. 12·5 ozs. before the experiment, and 48 lbs. 14·5 ozs. at its conclusion, giving a loss of 1 lb. 14 ozs., which was due to the action of the water peeling off the scale each time the cylinder was cooled.

Experiment 10.—A hollow brass cylinder, 6 inches long, 2 inches in diameter, and $\frac{1}{16}$th of an inch thick, was heated to redness and cooled by half-immersion thirty-four times.

The effect produced was the opposite to that which took place with the iron cylinders, being an expansion instead of a contraction at the water-line, the amount of which was ·175 inch, and it was also expanded on the lower edge ·1 inch (see fig. 16).

Fig. 16.



One-half of full size. The dotted line indicates the original figure.

Experiment 11.—A hollow gun-metal cylinder was heated to redness and cooled twenty times by half-immersion.

The thickness of metal being greater than in the last experiment, the effect at the water-line was much less, but the lower edge had expanded ·1 inch. It began to crack all over at the last cooling.

Experiment 12.—A hollow tin cylinder was heated in linseed-oil which was brought to a temperature of 400° Fahr.; it was cooled by half-immersion in water five times.

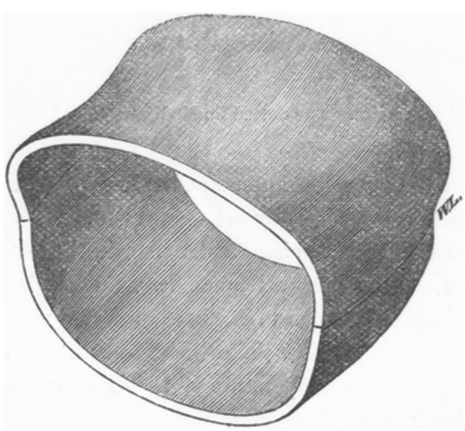
The form was not altered in the least, though the heat was raised in the last instance to the melting-point, as shown by the lower part of the cylinder beginning to melt.

Experiment 13.—A hollow zinc cylinder was heated and cooled by half-immersion fifty times.

It was heated in a wood furnace, the degree of heat to which it was brought being regulated by the melting of a piece of tin which was conveyed at the same time with it into the furnace. Several experiments with pieces of tin and zinc had been previously made, by means of which it was ascertained that in the same temperature tin melted in two-sevenths of the time requisite to melt zinc; hence when the zinc cylinder and piece of tin were placed in the furnace together, the time occupied by the tin in reaching its melting-point was carefully noted, and the cylinder was left in the furnace as long again as the time thus observed; by this means it was brought very nearly to its melting-point without incurring any danger of its actually melting. The last five times, however, it was allowed to remain a little longer in the flame; and the melting upon the top was retarded the last four times by placing a piece of iron upon it, which conducted heat from that part, allowing it to remain half a minute longer in the furnace.

The effect obtained was the same as that produced upon the brass cylinder (Exp. 10), or the opposite of what took place with iron; an

Fig. 17.



expansion of ·175 inch occurred upon the water-line, and of ·115 inch upon the lower edge.

Experiment 14.—The hollow wrought-iron cylinder was heated to redness and cooled by half-immersion on its *side*, instead of on its end as in other experiments, twenty times.

The effect was a very complicated one (see figs. 17, 18, and 19); the dotted lines show the original form.

Fig. 18. (Side view of fig. 17.)

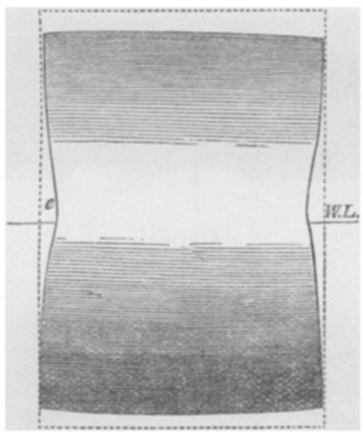
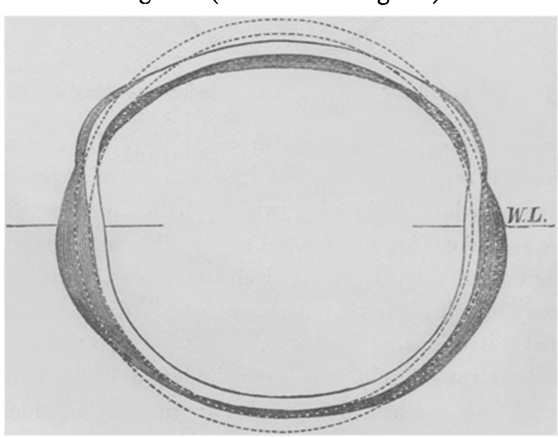


Fig. 19. (Front view of fig. 17.)



The three figures are one-sixth of full size.

Experiment 15.—A solid wrought-iron cylinder was heated to redness and cooled by half-immersion on its side twenty times.

The effect was of a similar nature to that of the last experiment (see figs. 20 and 21).

Fig. 20.

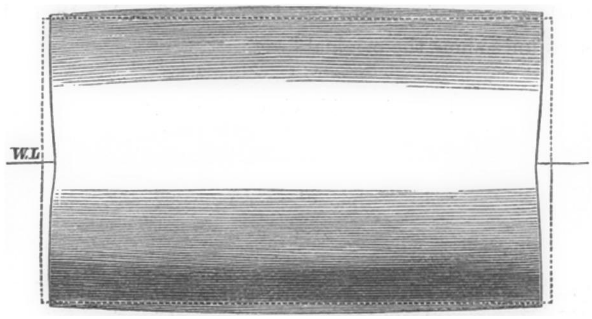
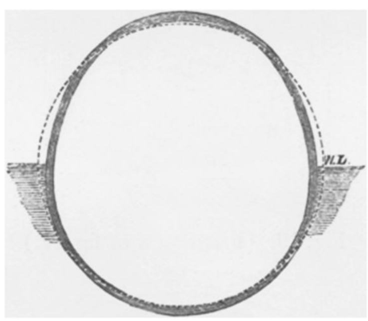


Fig. 21.



One-half of full size. The dotted line indicates original figure.

Experiment 16.—A hollow cast-iron cylinder, the dimensions of which were the same as those of the deep cylinder of Experiment 14, was heated to redness and cooled twice by half-immersion.

At the second cooling it fractured nearly all round, about an inch below the water-line. It expanded all over, but the expansion was least about an inch above the water-line, *i. e.* it did not contract to its original dimensions.

Experiment 17.—A solid cast-iron cylinder, 3 inches in diameter and 6 inches deep, was heated and cooled five times by half-immersion.

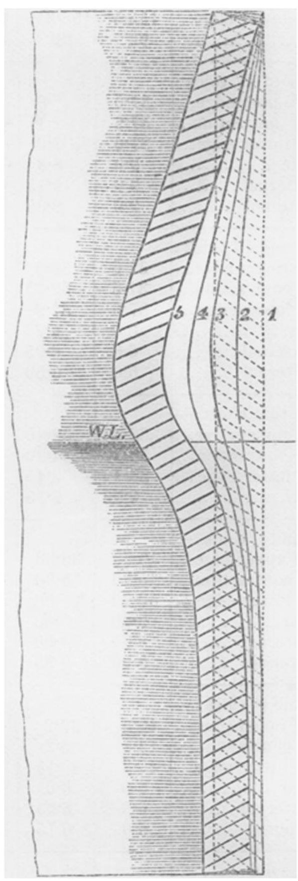
At the fifth cooling it cracked across the bottom; it also expanded

throughout, and the expansion was least a little above the water-line, *i. e.* it did not contract to its original dimensions.

The subjoined figures (half the full size) show the changes produced on the 9-inch cylinders after every five heatings. (Experiments 2 and 4.)

Fig. 22.

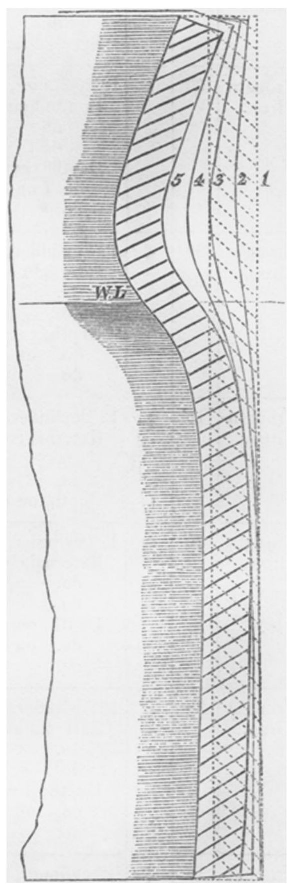
12″ Cylinder, 9″ high, ½″ thick. *Vide* fig. 4. Cooled by ½-immersion.



No. 1. External surface, original form.
2. ,, ,, after 5 coolings.
3. ,, ,, ,, 10 ,,
4. ,, ,, ,, 15 ,,
5. ,, ,, ,, 20 ,,

Fig. 23.

12″ Cylinder, 9″ high, ½″ thick. *Vide* fig. 7. Cooled by ⅔-immersion.



No. 1. External surface, original form.
2. ,, ,, after 5 coolings.
3. ,, ,, ,, 10 ,,
4. ,, ,, ,, 15 ,,
5. ,, ,, ,, 20 ,,

Tabulated Statement of the Results of the Experiments.

Number of experiment.	Kind of metal.	Number of coolings.	Amount of immersion.	Form of article, &c.	Dimensions, in inches. Before experiment.	After experiment.	Difference.
1[a].	Wrought iron.	5	½	Hoop-tire for a 4′ 2″ wheel:—			
				External circumf. of upper edge...	155·5	147·5	−8·0
				do. do. lower edge...	155·5	156·375	+0·875
				Bevel of face	90°	69°	−21°
2[b].	Wrought iron.	20	½	12″ cylinder, 9″ deep and ½″ thick:			
				Internal circumf. of upper edge...	37·6	37·6	0·0
				do. do. contraction..	37·6	32·1	−5·5
				do. do. lower edge...	37·6	37·0	−0·6
				Depth, perpendicular	9·0	8·8	−0·2
				do. on curve, external	9·0	9·15	+0·15
				do. do. internal	9·0	9·35	+0·35
2[c].	Wrought iron.	20	½	12″ cylinder, 6″ deep and ½″ thick:			
				Internal circumf. of upper edge...	37·6	36·9	−0·70
				do. do. contraction...	37·6	32·35	−5·25
				do. do. lower edge...	37·6	37·9	+0·30
				Depth, perpendicular...............	6·0	5·7	−0·30
				do. on curve, external	6·0	6·05	+0·05
				do do internal	6·0	6·30	+0·30
3[d].	Wrought iron.	10	½	12″ cylinder, 9″ deep, thin sheet:—			
				External circumf. of upper edge...	38·40	38·40	0·00
				do. do. contraction...	38·40	34·90	−3·50
				do. do. lower edge...	38·40	38·45	+0·05
				Depth, on curve	9·00	9·15	+0·15
4[e].	Wrought iron.	20	⅔	12″ cylinder, 9″ deep and ½″ thick:—			
				External circumf. of upper edge...	40·90	38·80	−2·10
				do. do. contraction...	40·90	35·00	−5·90
				do. do. lower edge...	40·90	40·00	−0·90
				Depth, perpendicular	9·00	8·80	−0·20
				do. on curve, external	9·00	9·00	0·00
				do. do. internal	9·00	9·35	+0·35
4[f].	Wrought iron.	20	⅔	12″ cylinder, 6″ deep and ½″ thick:—			
				External circumf. of upper edge...	40·8	37·2	−3·6
				do. do. contraction...	40·8	36·2	−4·6
				do. do. lower edge...	40·8	40·15	−0·65
				Depth, perpendicular...............	6·0	6·0	0·0
				do. on curve, external	6·0	6·05	+0·05
				do. do. internal	6·0	6·15	+0·15
5[g].	Wrought iron.	15	½	3″ cylinder, 6″ deep, solid:—			
				Circumference, upper edge	9·4	9·3	−0·1
				do. contraction	9·4	8·95	−0·45
				do. lower edge	9·4	8·95	−0·45
				Bulge on upper end	0·00	0·04	+0·04
				do. lower end	0·00	0·15	+0·15

[a] For remarks see end of Table, p. 470.

TABLE (*continued*).

Number of experiment.	Kind of metal.	Number of coolings.	Amount of immersion.	Form of article, &c.	Dimensions, in inches. Before experiment.	After experiment.	Difference.
6h.	Wrought iron.	15	$\frac{2}{3}$	3″ cylinder, 6″ deep, solid:—			
				Circumference, upper end	9·40	9·35	−0·05
				do. contraction.........	9·40	9·00	−0·40
				do. lower edge	9·40	9·05	−0·35
				Bulge on upper end	0·00	0·05	+0·05
				do. lower end	0·00	0·20	+0·20
7i.	Wrought iron.	20	$\frac{1}{2}$	Flat piece, 12″×6″×$\frac{1}{2}$″:—			
				Length on curve, upper edge ...	12·00	10·75	−1·25
				do do lower edge ...	12·00	12·10	+0·10
				Breadth, ends...	6·00	5·75	−0·25
				do. centre	6·00	6·00	0·00
				Upper edge, out of straight	0·00	0·60	+0·60
				Indentation on ends	0·00	0·30	+0·30
7k.	Wrought iron.	20	$\frac{2}{3}$	Flat piece, 12″×6″×$\frac{1}{2}$″:—			
				Length on curve, upper edge......	12·00	11·10	−0·90
				do. do. lower edge......	12·00	12·20	+0·20
				Breadth, ends	6·00	5·87	−0·13
				do. centre	6·00	5·95	−0·05
				Upper edge, out of straight	0·00	0·50	+0·50
				Indentation on ends	0·00	0·15	+0·15
8l.	Wrought iron.	15 10	0 total	12″ cylinder, 9″ deep, $\frac{1}{2}$″ thick do. do. do.	No	effect.	
9m.	Cast steel.	20	$\frac{1}{2}$	3″ cylinder, 6″ deep, solid:—			
				Circumference, upper edge	9·03	8·93	−0·10
				do. contraction	9·03	8·65	−0·38
				do. lower edge	9·03	8·93	−0·10
				Depth, perpendicular	6·00	6·10	+0·10
10n.	Brass.	34	$\frac{1}{2}$	2″ cylinder, 6″ deep, $\frac{1}{16}$″ thick:—			
				External circumf. of upper edge...	6·175	6·175	0·000
				do. do expansion ...	6·175	6·350	+0·175
				do. do. lower edge...	6·175	6·270	+0·095
11o.	Gun-metal.	20	$\frac{1}{2}$	3″ cylinder, 6″ deep, $\frac{1}{2}$″ thick:—			
				External circumf. of upper edge...	9·25	9·24	−0·01
				do. do. on water-line...	9·25	9·26	+0·01
				do. do. of lower edge..	9·25	9·38	+0·13
12.	Tin.	5	$\frac{1}{2}$	2″ cylinder, 5″ deep, $\frac{1}{4}$″ thick	No	effect.	
13.	Zinc.	50	$\frac{1}{2}$	3″ cylinder, 6″ deep, $\frac{1}{2}$″ thick:—			
				External circumf. of upper edge...	9·525	9·575	+0·050
				do. do. expansion ...	9·525	9·700	+0·175
				do. do. lower edge...	9·525	9·630	+0·105

TABLE (*continued*).

Number of experiment.	Kind of metal.	Number of coolings.	Amount of immersion.	Form of article, &c.	Dimensions, in inches. Before experiment.	After experiment.	Difference.
14[p].	Wrought iron.	20	$\frac{1}{2}$ on its side.	12″ cylinder, 9″ deep, $\frac{1}{2}$″ thick:—			
				External circumference of edges..	40·65	39·86	−0·79
				do. do. centre..	40·65	41·05	+0·40
				Depth on curve, part cooled in air.	9·00	9·00	0·00
				do. do. water-line.	9·00	8·25	−0·75
				do. do. in water...	9·00	8·80	−0·20
				Swell of side, 1″ below W.L. (at *a*, *b*)	0·00	1·00	+1·00
				Hollow of side, 4″ above do. (at *c*, *d*)	0·00	0·40	+0·40
				Longest ex. diam. 1″ below W. L.	12·94	14·275	+1·335
				Shortest do. at rt. angles to W.L.	12·94	12·00	−0·94
				Indentation of edges a little above water-line at *e*	0·00	0·45	+0·45
15[q].	Wrought iron.	20	$\frac{1}{2}$ on its side.	3″ cylinder, 5$\frac{3}{8}$″ deep, solid:—			
				External circumference of edges..	9·4	9·2	−0·2
				do do. centre.	9·4	9·475	+0·075
				Depth along part cooled in air ...	5·375	5·150	−0·225
				do. do. on W.L.	5·375	5·100	−0·275
				do. do. in water.	5·375	5·225	−0·150
				Longest diam. at rt. angles to W.L.	3·000	3·100	+0·100
				Shortest do. parallel with W.L. and a little below it	3·000	2·760	−0·240
16.	Cast iron.	2	$\frac{1}{2}$	12″ cylinder, 9″ deep, $\frac{1}{2}$″ thick:—			
				External circumf. of upper edge...	40·90	41·05	+0·15
				do. do. least expansion	40·90	40·95	+0·05
				do. do. of lower edge—	40·90	41·15	+0·25
17.	Cast iron.	5	$\frac{1}{2}$	3″ solid cylinder, 6″ deep:—			
				External circumf. of upper edge...	9·4	9·55	+0·15
				do. do. least expansion	9·4	9·50	+0·10
				do. do. of lower edge...	9·4	9·55	+0·15

Remarks.

[a] The width was unaltered, and the thickness of the upper edge slightly increased. Figs. 1 and 2. [b] Fig. 4. [c] Fig. 5. [d] Fig. 6. [e] Fig. 7. [f] Fig. 8.

[g] The fibre opened at the fifteenth cooling. Fig. 9.

[h] The fibre opened at the fifteenth cooling after having exhibited a slight crack for two or three previous coolings. Fig. 10.

[i] The thickness of the metal at the indentation on ends increased ·1″. Fig. 11.

[k] The thickness of the metal at the indentation on ends increased similarly to the last. Fig. 12.

[l] Cooled in air 15 times. Cooled in water 10 times.

[m] The ends became slightly rounded. Fig. 13.

[n] At the last cooling the lower end of the cylinder began to crumble away in the water. Fig. 16.

[o] The expansion of the lower end may probably be due to the cracking of the metal, which was greatest at that part.

[p] Figs. 17, 18, 19. There was an increased thickness of metal at *e*.

[q] Figs. 20, 21.

[The cause of the curious phenomenon described by Colonel Clerk in the preceding paper seems to be indicated by some of the figures, especially those relating to hollow cylinders of wrought iron, which are very instructive.

Imagine such a cylinder divided into two parts by a horizontal plane at the water-line, and in this state immersed after heating. The under part, being in contact with water, would rapidly cool and contract, while the upper part would cool but slowly. Consequently by the time the under part had pretty well cooled, the upper part would be left jutting out; but when both parts had cooled, their diameters would again agree. Now in the actual experiment this independent motion of the two parts is impossible, on account of the continuity of the metal; the under part tends to pull in the upper, and the upper to pull out the under. In this contest the cooler metal, being the stronger, prevails, and so the upper part gets pulled in, a little above the water-line, while still hot. But it has still to contract on cooling; and this it will do to the full extent due to its temperature, except in so far as it may be prevented by its connexion with the rest. Hence, on the whole, the effect of this cause is to leave a permanent contraction a little above the water-line; and it is easy to see that the contraction must be so much nearer to the water-line as the thickness of the metal is less, the other dimensions of the hollow cylinder and the nature of the metal being given. When the hollow cylinder is very short, so as to be reduced to a mere hoop, the same cause operates; but there is not room for more than a general inclination of the surface, leaving the hoop bevelled.

But there is another cause of deformation at work, the operation of which is well seen in figs. 2 and 3. Imagine a mass of metal heated so as to be slightly plastic, and then rapidly cooled over a large part of its surface. In cooling, the skin at the same time contracts and becomes stronger, and thereby tends to squeeze out its contents. This accounts for the bulging of the ends of the solid cylinders of wrought iron and the rents seen in their cylindrical surface. The skin at the bottom is of course as strong as at the sides in the part below the water-line; but a surface which resists extension far more than bending has far less power to resist pressure of the nature of a fluid pressure when plane than when convex. The effect of the cause first explained is also manifest in these cylinders,

although it is less marked than in the case of the hollow cylinders, as might have been expected.

The tendency of the cooled skin of a heated metallic mass to squeeze out its contents appears to be what gives rise to the bulging seen near the water-line in the hollow cylinder of brass. Wrought iron, being highly tenacious even at a comparatively high temperature, resists with great force the sliding motion of the particles which must take place in order that the tendency of the cooled skin to squeeze out its contents may take effect; but brass, approaching in its hotter parts more nearly to the state of a molten mass, exhibits the effect more strongly. It seems probable that even in the case of brass a *very* thin hollow cylinder would exhibit a contraction just above the water-line. Should there be a metal or alloy which about the temperatures with which we have to deal was stronger hot than cold, the effect of the cause first referred to would be to produce an expansion a little below the water-line.—G. G. S.]

March 12, 1863.

Dr. WILLIAM ALLEN MILLER, Treasurer and Vice-President, in the Chair.

His Grace the Archbishop of York was admitted into the Society.

The following communications were read:—

I. "On the Influence of Temperature on the Electric Conducting Power of Thallium and Iron." By A. MATTHIESSEN, F.R.S., and C. VOGT, Ph.D. Received February 12, 1863.

(Abstract.)

Thallium.—The experiments detailed in this paper were made with specimens of thallium lent to us by Mr. Crookes and Professor Lamy of Lille. The values obtained for the conducting power, together with the formulæ for the correction of the conducting power for temperature of the different specimens, were:—

For Mr. Crookes's metal,

1st wire.	2nd wire at 0°.
$\lambda=9{\cdot}364-0{\cdot}037936t+0{\cdot}00008467t^2$;	9·169.